Sustainable Energy

Reinventing Rice for a World Transformed by Climate Change

UC Davis plant geneticist Pamela Ronald wants to create rice varieties that can survive in harsher conditions, including more frequent droughts.

by James Temple May 4, 2017

Plant geneticist Pamela Ronald in her lab's greenhouse at UC Davis.

MOLLY MATALON

Pamela Ronald stands in front of two rows of rice plants, sprouting from black plastic pots, in a stifling greenhouse on the edge of the University of California, Davis, campus.

Researchers in Ronald's plant genetics lab starved the grasses of water for more than a week. The ones on the right, the control in the ongoing experiment, are yellowing and collapsing. The leaves in the adjacent plants, equipped with an added gene, are thick, tall, and green.

The hope is that these or similar genetic alterations could help rice and other crops survive devastating droughts, preventing food shortages in some of the poorest parts of the world. Ronald, a trim scientist with short brown hair, smiles as she looks down at the early results.

She has spent the last three decades working to make rice, a food staple for more than half of the world's population, more resistant to environmental stress. She was a central player in one the greatest recent success stories in plant genetics, isolating a gene that allows rice to survive extended periods of flooding. It's a huge challenge in low-lying parts of Asia, wiping out around four million tons of rice each year in India and Bangladesh alone. A decade after her lab's discovery, more than five million farmers grow rice varieties engineered with the so-called Sub1 gene, covering more than two million hectares across Asia.

The latest research could be even more significant, as climate change ratchets up the frequency and intensity of droughts across large swaths of the Earth, threatening the food security and stability of entire nations. The number of extreme droughts could double by the end of the century, devastating fields and farmers across South Asia and sub-Saharan Africa.

Ronald's work provides a powerful statement for the potential of modern genetic tools to preserve livelihoods and lives, offering a counter narrative to the widespread fears and distortions surrounding genetically modified crops (see "Why We Will Need Genetically Modified Foods"). "This focus on genes in our food is a distraction from the really, really important issues," she says. "How can we reduce the use of toxic inputs? How can we feed the poor and malnourished? How can we be sure that farmers have access to seeds, and that consumers can afford the food that's produced?"

Pamela Ronald gets hands-on with a rice plant.

MOUNTAIN FLOWERS

Ronald grew up San Mateo, California. Her mother was a talented gardener and cook. Her father was a businessman who fled Nazi Germany as a child.

Years after arriving in California, he built a 500-square-foot cabin in south Lake Tahoe, where the family spent summer vacations. One hot day when she was around 15, Ronald and her brothers hiked a steep path into the High Sierra. At the saddle, they happened upon a couple hovered over a book. They were a pair of professional botanists who were cataloguing flowers. She had developed an affection for plants from the time she spent with her mother in the garden and kitchen, but this was the first time she realized you could make a living working with them.

In the late 1980s, during her PhD program at UC Berkeley, Ronald started working with peppers and tomatoes. But as she began her postdoctoral work, she decided to shift her focus to rice, realizing that even small advances in stress tolerance for such a critical crop could help a lot of people. Tomatoes and peppers are "important for salad, but I wanted to work on supper," she says. "I wanted to work on a staple food crop, I wanted to move to something more important."

Ronald arrived at UC Davis as an assistant professor in 1992. Her small, square office carries signs of the work she's done since, including Asian tapestries, illustrations and covers from journal articles, and arrayed copies of "Tomorrow's Table: Organic Farming, Genetics, and the Future of Food," the 2008 book she co-wrote with her husband, Raoul *Adamchak*, who teaches organic farming at UC Davis.

Ronald's work on flood-tolerant rice started in the mid-1990s, as a U.S.

Department of Agriculture-funded collaboration with colleagues at UC Davis. Over the course of a decade, the team pinpointed and isolated the Sub1 gene in an ancient but unpopular Indian rice variety, known as landrace, that enables it to survive even when it was submerged under water for more than two weeks. Since then, the Philippines-based International Rice Research Institute, backed by more than $70 million in funding from the Bill and Melinda Gates Foundation, has bred that gene into 10 popular Asian rice varieties. In turn, the nonprofit put the seeds into the hands of farmers in India, Bangladesh, Indonesia, Nepal, and other nations.

Rice is a tough crop to grow, requiring a lot of work and a lot of water. Too much all at once kills it, but so does too little. It takes just a week without rain to significantly decrease yields in hilly rice-growing areas.

The challenges of rice production are only bound to get worse in many areas, as climate change raises temperatures, reduces rainfall in certain places, and increases flooding or sea level rise in others.

Under a high greenhouse gas emissions scenario, rice yields would be nearly 15 percent lower than otherwise expected at midcentury, and prices would be 30 percent higher, according to a 2015 report in Environmental Research Letters.

Shifting farming practices and the fertilizing effect of increased carbon dioxide could offset some of these climate impacts. But it's going to become much harder and more expensive to maintain yields in many areas, and rich nations will have far greater capabilities than poor ones to make the necessary changes, says Keith Wiebe, senior research fellow at the International Food Policy Research Institute.

Crops altered to survive harsher environmental conditions will be a crucial tool for helping "small farmers who produce in the more tropical environments, who will be the most exposed to climate shocks," says Alain de Janvry, a UC Berkeley economist.

The work at Ronald's lab on drought-tolerant rice varieties is in an early phase. She declines to discuss details, including the basic approach, until they've conducted additional experiments to verify the initial results and published their findings.

Other scientists around the world are also racing to develop drought-resistant crops, and have already achieved some advances, including sprays, hybrids, and genetic alterations that help crops switch into water-preserving modes at earlier signs of trouble, or otherwise enable plants to get by with less moisture.

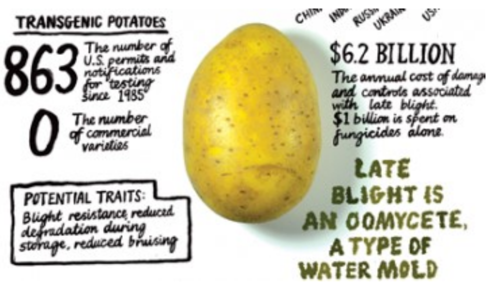
But greater advances will be required to confront the growing challenges ahead, and drought tolerance is a tricky problem. The trait generally involves various genes and cellular communication pathways. It's crucial that any improvements not come at the expense of yield, taste, and other qualities important to farmers and consumers. And there would seem to be hard limits on how much can ever be achieved, as all plants need water.

OVERCAST

On an overcast Saturday in late April, Ronald stood on stage at a brick plaza on the edge of the San Francisco Bay, addressing the sign-wielding crowd gathered for the March for Science. "Science is based on data, not on alternative facts," she said, pausing for applause at the end of most sentences. "Science is not a buffet where people can pick and choose the parts they like, and throw out the rest."

But people do, of course. The weakest applause line of her speech before the crowd, gathered largely to protest the Trump administration's denial of climate science, was when she said that science had improved California's fruits, vegetables, and nuts. In other words, when she took a moment to acknowledge a field that could help address some of the problems arising from a changing climate. It was typical Ronald, determined to assert where she believes the science leads, whomever the audience. Genetically modified crops have become incredibly contentious, widely portrayed as reckless attempts to tinker with Mother Nature for the sole benefit of seed conglomerates. But Ronald argues the body of science shows they've been both safe and beneficial. She publicly sparred with the Union of Concerned Scientists on these issues, suggested Greenpeace was "misinterpreting data," and criticized Vermont's GMO labeling laws in these pages (see "How Scare Tactics on GMO Foods Hurt Everybody"). Taking on the role of public face for the field has, of course, earned her critics. GMOWatch called her a "GMO propagandist," and reveled in highlighting that her lab retracted a pair of papers in 2013, due to mislabeled bacterial strains and a faulty test. (Others praised the lab for discovering their own error, and taking pains to correct the record.)

The gravest concerns over GMOs center on transgenic plants, such as the soybeans or corn engineered with a foreign bacterial gene that allowed for the use of Monsanto's Roundup herbicide.



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But Ronald's research highlights the broader definition and promise for genetic alterations. Sub1 rice sidestepped any anti-GMO backlash because, while it required the tools of modern genetics to isolate and express the gene, it doesn't carry along any non-rice DNA. The trait from one rice variety was added to others through modern breeding methods, accelerated by analyzing the DNA of offspring to avoid false paths.

Ronald notes that every major food crop has been altered by human hands in one way or another. And some of the most important advances in the future, to improve yields, nutrition, environmental tolerance, or biofuels, may be possible only with increasingly powerful gene-editing technologies such as TALENs and CRISPR.

What should matter to lawmakers, regulators, or critics isn't which implement was pulled from the ever-advancing genetic toolbox, but whether it produced a positive or negative impact on human health or the environment. At this point, we have a four-decade track record of genetic engineering in plants, medicine, and cheese, with no evidence of harm, Ronald says.

The danger is that unfounded fears could come at the expense of easing real human suffering, if misguided regulations slow down the science, or protests prevent seeds and crops from reaching the farmers and consumers who need them most. For Ronald, the real goal should be sustainability in the broadest sense, applying whatever combination of breeding, organic farming, or genetic technology helps us feed a growing population without exacting a higher environmental cost.

"We need to make policy based on evidence, and based on a broader understanding of agriculture," Ronald says. "There are real challenges for farmers, and we need to be united in using all appropriate technologies to tackle these challenges."